Available online at www.sciencedirect.com
ScienceDirect
Procedia CIRP 48 (2016) 425 – 430
www.elsevier.com/locate/procedia

23rd CIRP Conference on Life Cycle Engineering

Embedding the circular economy in investment decision-making for capital assets – a business case framework

M. Korse[a], R.J. Ruitenburg.[b,c]*, M.E. Toxopeus[b], A.J.J. Braaksma[b]

[a]Gemeente Haarlemmermeer, Raadhuisplein 1, 2132 TZ Hoofddorp, the Netherlands
[b]University of Twente, De Horst 2, 7522 LW Enschede, the Netherlands
[c] Liander N.V., Utrechtseweg 68, 6812 AH Arnhem, the Netherlands

* Corresponding author. *Tel.:* +31- 53 489 4022; *E-mail address:* r.j.ruitenburg@utwente.nl

Abstract

Industry shows an increasing interest in the circular economy. However, circularity for physical capital assets is still ill-defined and existing models are complex and information dependent hindering implementation. This paper addresses these gaps by operationalizing circular economy principles and developing a suitable business case framework embedding circularity. Following the Design Science Methodology, a framework was developed based on circularity and investment decision-making literature and requirements from a Dutch electricity grid operator. An initial evaluation showed that the framework supports selecting the preferred circular investment scenario and can be generalized to other industries.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering

Keywords: investment decision making; circular economy; sustainability; asset management

1. Introduction

Recently, the Circular Economy (CE) started to gain more attention. As opposed to the current "linear" economy, this model aims to keep resources at their highest utility (at their highest value and potential) within the economy [1]. This proposition of CE is an answer to increasing resource scarcity. Availability and supply of resources is becoming less secure and prices become more volatile. CE addresses social and environmental challenges and it provides economic benefits to businesses [2].

Such challenges were also recognized by Liander, a Dutch distributor and network operator (DNO) for gas and electricity that aims to provide a sustainable and reliable energy service. The infrastructure that it maintains exists of an extensive network of durable physical capital assets. One of the challenges is to replace aging assets adequately. At the same time, recent technological developments such as decentralized production of renewable energy require an expansion of its infrastructure capacity to continue a high level of availability.

Within this context, Liander needs a tool to support sustainable decisions on asset investments. In line with Liander's ambitions to implement CE within their asset management, environmental sustainability should be part of the sustainable investment decisions methodology. These ambitions as well as physical and technical challenges affect Liander's business proposition requiring a change in its business case model for physical capital assets.

Business cases allow a company to steer towards predefined goals in advance. Common business cases models include the *business objectives*, *cost and benefits* and *risk valuation* [3]. Resulting asset investment decisions are based on the trade-offs between these values. So far, few publications have been found that discuss the addition of environmental sustainability to the business case, and CE in particular. Also, as Niekamp *et al.* state, in the field of asset management there is a lack of guidance for considering sustainability aspects [4]. Next to that, CE principles in relation to physical capital assets are not clearly defined.

Peer-review under responsibility of the scientific committee of the 23rd CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.04.087

Hence, no useful method is yet available to make CE based decisions for physical capital assets.

The aim of this paper is to develop a business case framework for environmental sustainability based on CE principles. The paper will especially address the definition of CE for capital assets and the implementation of this definition within a business case framework. It will result in a practical decision support tool to aid asset managers in making investment decisions for capital assets. The Design Science Research (DSR) methodology described in section 2 is used to guide this process.

The literature paragraph, section 3, focusses on two fields: business cases for sustainability (BCS) and CE. The constituents of traditional business cases as well as current frameworks for BCS will be discussed. Considering CE, its definition and principles will be addressed as well as indicators to measure environmental sustainability from a CE perspective.

Section 4 will link CE to the business case by developing a framework that includes sustainability. The following section will demonstrate this framework through an application on distribution transformers. These capital assets are commonly present and representative for the electrical infrastructure.

The paper will conclude with an evaluation and discussion of the results in section 6 and 7.

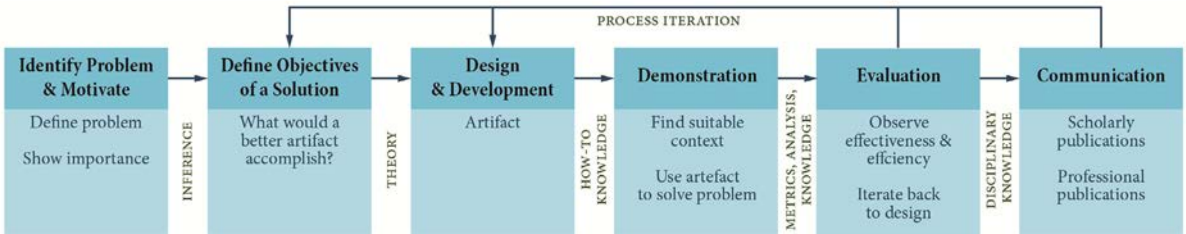
2. Design science research methodology (DSR)

To design a tool that supports sustainable asset investment decision-making integration of various disciplines is necessary. Besides integration, the theoretical knowledge needs to be translated into a practical tool for a real world problem. By using DSR to tackle this complex problem in a reliable way, a relevant tool or "artefact" for an unsolved and important business problem [5] will be developed. As Hevner *et al.* [6] states, DSR can help solve problems characterized by "unstable requirements and constraints based upon ill-defined […] contexts". The methodology develops both knowledge and an artefact during the various process steps (fig 1). In this paper just the results will be presented.

The knowlegde needed to develop the artefact is based upon a literature review, observations made while partaking in Liander's organization and through meetings with relevant stakeholders internal and external of the organization. This process supported the identification of any preconditions that the framework needs to comply with.

To guide the design process, the contextual knowledge was translated into specific design criteria. These design criteria were used to create a clear scope for the development of the tool and to test the developed tool.

Fig 1. Design Science Research Methodology. Adapted from Peffers *et al*. [5]



3. Literature

3.1. Business case models for sustainability (BCS)

Business case models define the business proposition and values of an organization. An example of a traditional business case model is the IT investment decision model of Remenyi [7]. This comprehensive model appraises the business outcome, stakeholders, technical quality, strategic alignment and risk assessment of an IT investment. The high quality standards within the capital asset industry are similar to these five business case elements. Remenyi's model may therefore be adopted within capital asset sectors. However, the model does not include environmental sustainability nor CE. The literature review of business case models by Berghout & Tan [3] showed that sustainability is usually not taken into account in business cases. This is a deficit in current methodologies, as the demand for including environmental sustainability is increasing [8].

Common methods for organizations to value sustainability are [9] life cycle assessment (LCA) [10], life cycle costing (LCC) [11] and cost-benefit analysis (CBA) [12]. These methods allow organizations to analyze and identify their environmental impact [3] and could fit within a BCS. While LCC and CBA are methods that measure the financial impact and are often part of the business proposition [9], LCA is more comprehensive and measures impact in non-financial terms. This allows the environmental impact to be explicitly distinguishable within analyses. On the other hand, the comprehensiveness of an LCA makes the analysis time-consuming and increases the complexity of a BCS. To make a BCS practical, it is important to overcome its complexity. Complexity is often induced by various incompatible parameters and the challenge of measuring long term benefits of intangible assets [8].

Business case models that specifically include CE were not found. A method that comes closest to the scope of this study is the Sustainable Water Industry Asset Resource Decision (SWARD) model [13]. This model assesses various indicators within four top level constituents: economic, environmental, social and technical criteria. Although the SWARD model is too specific for the aim of this research, the explicit inclusion of environmental sustainability makes it a good example for a BCS.

3.2. Circular Economy

At the moment of this study's research phase few articles on CE were published [14]. An analysis of the literature showed that amongst the various scholars differences in definition and principles of CE can be found. These differences occur due to a difference in cultural perspective, legitimization, application and scoping [14]. Therefore, it should be noted that not all CE principles can be applied in every context and that specific applications may require a unique set of principles.

Apparently no general acknowledged definition of CE is present [15–17]. To meet the need for this study, it is necessary to define CE from an environmental sustainability perspective in such a way that it can be embedded within a business case framework. The resulting indicators should be applicable and practical within infrastructure asset management.

3.3. Operationalizing Circular Economy Principles

Even though no general accepted definition is present, a wide variety of CE principle sets have been developed in order to measure CE. Unfortunately, in most cases it is unclear what the fundamental principle was to base the indicators on. For example, the NDRC indicator system focusses only on resource utilization [18] while Bastein *et al.* also include ecological footprint [2]. These inconsistencies can cause confusion and incompatibilities, and may even increase the bias of CE performance assessments. To render out this bias within a BCS, the core principles of CE must be clearly defined. This is done through an analysis of eleven indicator sets (table 1), relevant to the scope of this study.

By grouping indicators that measure a similar aspect into overarching categories, the amount of indicators has been reduced (figure 2). Subsequently, the number of indicators within each category indicates the apparent importance of that category within CE.

Table 1. Overview of indicator sets for CE and related topics.

Bastein *et al.* [2],	Geng *et al.* (B) [22],
Circular Scorecard [19],	MEP indicator system [18],
Circularity Calculator (EMA) [1],	NDRC indicator system [18],
Cradle to Cradle [20],	Resource Passport [23],
CSR Performance Ladder [21]	Schoolderman *et al.* [24],
Geng *et al.* (A) [22],	

Fig 2. Categorization of top-level principles and indicators found in literature on and related to CE: percentage of indicators that the category accounts for.

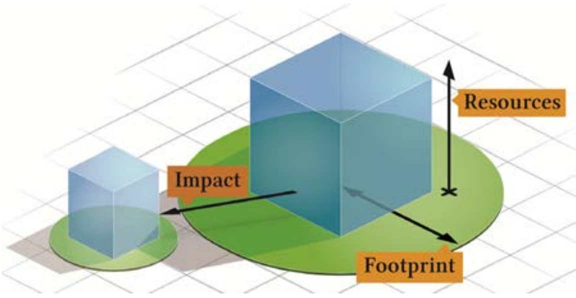


Fig 3. Relation of three CE-deduced environmental sustainability indicators.

In common business case frameworks like Remenyi's [7] or SWARD [13], the *economic*, *social* and *organization* categories are already represented. The categories *material usage*, *eco-footprint* and *impact* combined can contribute to the aim of explicitly including environmental sustainability from a CE perspective into the framework. The remaining categories, *energy* and *emissions*, have been included within the material usage and eco-footprint category. This was done as energy production is derivative of material usage and emissions affect the eco-footprint. For example, power plants incinerate fossil fuels and CO_2. By embedding them in existing categories, double counting is avoided.

This results in the following three elements that operationalize CE principles from an environmental sustainability perspective:

1. *Resource usage* can be seen as a direct, 1st degree, effect. It is the quantitative effect on the global stock of materials and fossil energy.
2. *Ecological footprint* is the quantitative effect on the global capacity to regenerate and act as sink. It is a 1st degree effect on space.
3. *Environmental impact* is an indirect, 2nd degree, qualitative effect of any economic activity on the ecosystems.

An example of these three indicators can be given on the basis of a coal fire. The effect of (1) resource usage is less coal, (2) the ecological footprint is the destruction of nature at coal mines and the saturation of the air with CO_2[1], and (3) the environmental impact is the greenhouse effect. Figure 3 illustrates these three indicators in relation to each other.

4. Development of business case framework

4.1. Template framework

As a suitable BCS framework was not found, a BCS was developed within this study based upon traditional business cases relevant to the physical capital asset sector. Remenyi's framework was identified as a suitable template due to the constituents it covers: the technology, strategic, stakeholders, financial and risks. The first four describe separate domains, while risks are assessed upon these four constituents.

[1]CO_2 is therefore also represented within the proposed BCS framework.

Even though Remenyi's framework is relevant to this study, its indicators do not all match the aspects that are found to be important within the electricity infrastructure sector. Using the process phases of SWARD, three applicable indicators per constituent (table 2) were selected. This was done by taking into account the indicators used by Liander and those present in Remenyi's framework. This leads to a template framework to which sustainability can be added.

A limited number of indicators keeps the model lean and practical. The selected indicators assess different, non or little overlapping, aspects of the constituent. However, as each BCS has its specific context, diverting from these generic indicators can be done by replacing or adding additional indicators.

4.2. Adding environmental sustainability to the framework

To develop a BCS from the template framework, the three operationalized CE elements need to be embedded. They can be embedded within the current constituents or combined into a newly added constituent. Because of the complexity of sustainability and the need to prevent losing intangible effects such as environmental impacts, environmental sustainability is added as a separate constituent. The three elements (resource usage, ecological footprint and environmental impact) can be measured either quantitatively or qualitatively and hence act as indicators for this constituent.

Assessment of these indicators can be done by means of applying existing tools. For resource usage material flow analyses or comprehensive reutilization scores can be used. Environmental impact can be assessed using part of life cycle analysis tools and ecological footprint can be measured using a comprehensive, non-carbon, footprint calculator.

4.3. Risk and opportunity management

Risk management is taken separately from the other constituents and not valued as an indicator within each constituent because of the importance of risk management. Even small chances may result in large impacts when dealing with physical capital assets within the energy infrastructure. Hence, risks tend to influence the business case negatively.

On the other hand, there is the chance that certain opportunities may occur. Opposite to risks, can influence the business case positively. Hence, the risk assessment can be both positive (the chance and impact of an opportunity) and negative (the chance and impact of a risk). The resulting BCS framework is depicted in figure 4.

Fig 4. Business case for sustainability framework.

4.4. Asset investment decision-making

The business case framework is the basis for asset related decisions. To translate the framework into a decision-aiding tool various methods can be used. This process will not be extensively discussed in this paper but based upon previous research on the topic [4,25,26].

Multi-criteria decision analyses (MCDA) can address complex problems with conflicting objectives [4] and fit the characteristic of a BCS. To prevent comparing or summation of indicators based on different incompatible parameters a pairwise outranking method is suggested [27]. Outranking gives insight into the decision problem without creating biased outcomes.

5. Case Study: Business Case Framework Evaluation

The developed BCS framework has been evaluated done through a case study of an asset investment decision problem. The asset management department of Liander is continuously replacing aged assets and expanding its electricity infrastructure to meet future needs. Due to technological improvements, new types of assets such as cables, distribution transformers and switches become available. This results in a decision problem in which the costs and benefits of each technology need to be assessed and compared.

The case study focusses on distribution transformers (DT) (figure 5). DTs are static devices that are mainly constructed of steel, copper, mineral oil and some paper. The current population (40,000) that Liander maintains have rated loads ranging from 100kVA to 2,500kVA and have been designed for an average lifetime of 40 years. Their replacement rate is about 1-2% per year, mostly based on preventive replacement criteria instead of failure.

Table 2. Suggested indicators for the business case for sustainability framework.

Economic	Technology	Stakeholders	Strategic	Sustainability	Risks
Net present value	Functional requirements	Stakeholder dependency	Business goals alignment	Resource usage	Economic
Return on investment	Physical requirements	Stakeholder collaboration	Chain partner alignment	Environmental impact	Technology
Total cost of ownership	Operational requirements	Stakeholder responsibility	Governmental alignment	Ecological footprint	Stakeholder
					Strategic
					Sustainability

Table 3 gives the result of an MCDA for three DT technologies: the use of an aluminum coil, amorphous cores, or using bio-oil as insulation and coolant. The benchmark is the current standard transformer within Liander's infrastructure. The assessments were based upon expert sessions within Liander and supported by literature on the various technologies. The MCDA in table 3 shows the relative scores of the case study as an illustration of the assessment.

The assessment shows that each technology has its pros and cons in relation to the benchmark DT. The transformer with aluminum coil is most similar to the benchmark and scores only slightly better on a few indicators than the benchmark. This is the result of aluminum being a less scarce material than copper. Dependency on supply chain and stakeholders is therefore less critical. The positive sustainability risk translates into a sustainability opportunity.

The DT with an amorphous core shows some large negatives (reliability) as well as large positives (energy efficiency). This is an indication that this new technology is promising but not yet sufficiently reliable. This is mainly caused by the brittleness of the amorphous material, which complicates production, transport and increases contamination of the insulating mineral oil. Further development of the technology may increase its potential and opportunities for future investments.

Table 3. Assessment of DT technologies illustrating benchmarked scores. A positive score performs better than the benchmark, a negative worse.

Constituent	Indicator	Aluminum	Amorphous	Bio-oil
Technical appraisal	Functional performance	1	0	0
	Physical performance	0	-1	1
	Operational performance	0	-2	-1
Economic appraisal	Net present value	0	0	0
	Return on investment	0	0	0
	Total cost of ownership	0	1	1
Stakeholder appraisal	Stakeholder dependency	0	-2	0
	Stakeholder collaboration	1	0	1
	Stakeholder responsibility	0	-1	1
Environmental sustainability	Resource usage	1	2	2
	Ecological footprint	0	0	0
	Environmental impact	0	1	1
Strategic alignment	Business goals alignment	1	1	0
	Chain partner alignment	0	-1	0
	Governmental alignment	1	1	1
Risk valuation	Technical risks	0	0	1
	Economic risks	0	-1	0
	Stakeholder risks	0	0	0
	Sustainability risks	1	2	2
	Strategic risks	0	0	1

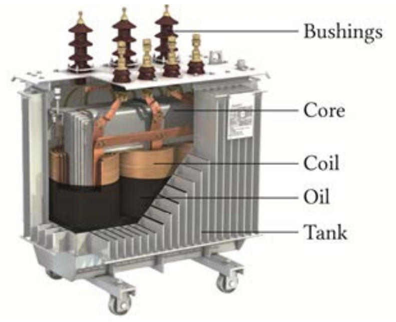


Fig 5. A cross section of a common distribution transformer.

The DT that uses bio-oil as coolant instead of commonly used mineral oil has most advantages over the benchmark. Although more expensive, bio-oil slows down aging and improves recyclability, which has a large positive effect on resource usage and makes the financial business case positive over the entire life cycle. One of the drawbacks of investing in bio-oil mentioned by Liander, is the burden to manage two different types of oil-flows. This explains the negative score on operational performance as logistics need to be adjusted.

The aluminum option scores slightly less than the bio-oil but has no negatives. It may therefore be easier to implement on the short term while bio-oil may have greater advantages on the long run. The amorphous DT has too many negative scores to be viable at this stage. However, as technology progresses the option may be reassessed.

This result was found to be counter-intuitive from asset management perspective as the amorphous DT was expected to score better and the bio-oil DT to score worse. This shows the importance of objective assessment that does not focus on hypes but includes a comprehensive range of indicators.

6. Conclusion

The aim of this study was to develop a sustainable business case for physical capital assets using CE as a basis to value environmental sustainability. To do so, core principles of CE had to be identified as no general acknowledged definition is present. Three elements were found to describe this: resource usage, ecological footprint and environmental impact.

To develop a balanced and comprehensive framework, environmental sustainability was included into the BCS as a separate constituent. That led to a BCS of six constituents: financial appraisal, technical assessment, stakeholder appraisal, strategic alignment, environmental sustainability and risk valuation. To keep the framework and decision aiding tool practical it is suggested to assess three indicators per constituent. The paper used constituents and indicators that are relevant within the scope of this study.

The developed BCS framework has been evaluated in an application on distribution transformers. It was found to be a practical framework and support decision makers in giving better insight in the trade-offs.

7. Discussion

As definitions of CE vary throughout literature, more research is necessary to develop a common ground and syntax of CE. Most indicators that try to measure CE, lack substantiation. Therefore, research should not only focus on the implementation of CE but also on the mechanisms behind CE to enable the deduction of consistent core principles.

While the core principles may not be generally defined, it is generally acknowledged that CE can be an answer to more efficient resource usage. The field of asset management, and especially physical capital assets that contain many scarce materials, is therefore a key research area. However, CE has had little attention within asset management literature.

Current business practices are often structured to be cost-efficient and avoid financial risks. Depreciation and discounting are such measures. However, when depreciating an investment to zero, the financial incentive is lost to reuse or recycle the asset at its end of life. We propose to discount towards the remaining value of the resources.

Within this study, material resources were found to be an important aspect of CE. The supply chain depends on these resource flows. Therefore, the asset manager that takes CE explicitly into account also affects the rest of the supply chain through its decisions. The impact on the supply chain is taken into account within the stakeholder appraisal indicator.

The developed BCS framework explicitly excludes energy and emissions as separate indicators to avoid double counting. However, policymaking is currently carbon focused and the energy transition highly influences business propositions within the energy sector. Therefore, it is suggested that for the time being energy usage and CO_2 could explicitly be included in BCS as discussed in section 3.3.

Economic and environmental sustainability have both been accounted for within the developed business case framework. However, to make it a truly sustainable business case, social impacts should also be included. The framework does give the opportunity to do so through the stakeholder responsibility indicator. But due to the complex nature of social impact, more research would be necessary to make substantiated claims on how to include this within a business case.

The current framework has been evaluated with a single case study consisting of various decision problems of which one has been presented within this paper. Further testing of the framework is suggested to improve its reliability and generalizability. The reliability will improve if replicability of the framework is found. Improvement of the generalizability requires testing within other industries in and outside the scope of physical capital assets for the energy sector.

Acknowledgements

The authors thank Liander N.V. for providing the opportunity and close collaboration in this research project.

References

[1] Ellen MacArthur Foundation. Towards the Circular Economy Economic and business rationale for an accelerated transition. vol. 1. Ellen MacArthur Foundation; 2012.

[2] Bastein T, Roelofs E, Rietveld E, Hoogendoorn A. Opportunities for a Circular Economy in the Netherlands. TNO; 2013.

[3] Berghout E, Tan C-W. Understanding the impact of business cases on IT investment decisions: An analysis of municipal e-government projects. Inf Manag 2013;50:489–506. doi:10.1016/j.im.2013.07.010.

[4] Niekamp S, Bharadwaj UR, Sadhukhan J, Chryssanthopoulos MK. A multi-criteria decision support framework for sustainable asset management and challenges in its application. J Ind Prod Eng 2015;32:23–36. doi:10.1080/21681015.2014.1000401.

[5] Peffers K, Tuunanen T, Rothenberger MA, Chatterjee S. A Design Science Research Methodology for Information Systems Research. J Manag Inf Syst 2007;24:45–77. doi:10.2753/MIS0742-1222240302.

[6] Hevner AR, March ST, Park J, Ram S. Design Science in Information Systems Research. 2MIS Q 2004;28:75–105.

[7] Remenyi D. IT investment making a business case. 1st ed. Oxford: Butterworth-Heinemann; 1999.

[8] Salzmann O, Ionescu-somers A, Steger U. The Business Case for Corporate Sustainability. Eur Manag J 2005;23:27–36. doi:10.1016/j.emj.2004.12.007.

[9] Hoogmartens R, Van Passel S, Van Acker K, Dubois M. Bridging the gap between LCA, LCC and CBA as sustainability assessment tools. Environ Impact Assess Rev 2014;48:27–33. doi:10.1016/j.eiar.2014.05.001.

[10] Finnveden G, Hauschild MZ, Ekvall T, Guinée J, Heijungs R, Hellweg S, et al. Recent developments in life cycle assessment. J Environ Manage 2009;91:1–21.

[11] Márquez AC, Márquez CP, Fernández JFG, Campos ML, González-Prida Díaz V. Life Cycle Cost Analysis. In: van der Lei T, Herder P, Wijnia Y, editors. Asset Manag. State Art Eur. from a Life Cycle Perspect., Dordrecht, the Netherlands: Springer Netherlands: Dordrecht; 2012, p. 81–99.

[12] Mishan EJ, Quah E. Cost-benefit analysis. Routledge; 2007.

[13] Butler D, Jowitt P, Ashley R, Blackwood D, Davies J, Oltean-Dumbrava C, et al. SWARD: decision support processes for the UK water industry. Manag Environ Qual An Int J 2003;14:444–59. doi:10.1108/14777830310488676.

[14] Korse M. A Business Case Model to Make Sustainable Investment Decisions. University of Twente, 2015.

[15] Andersen MS. An introductory note on the environmental economics of the circular economy. Sustain Sci 2006;2:133–40. doi:10.1007/s11625-006-0013-6.

[16] Dajian Z. Background, Pattern and Policy of China for Developing Circular Economy. Chinese J Popul Resour Environ 2008;6:3–8. doi:10.1080/10042857.2008.10684889.

[17] Yuan Z, Bi J, Moriguichi Y. The Circular Economy: A New Development Strategy in China. J Ind Ecol 2008;10:4–8. doi:10.1162/108819806775545321.

[18] Su B, Heshmati A, Geng Y, Yu X. A review of the circular economy in China: moving from rhetoric to implementation. J Clean Prod 2013;42:215–27. doi:10.1016/j.jclepro.2012.11.020.

[19] Circle Economy, Plas A van der. Circular Scorecard 2014.

[20] McDonough Braungart Design Chemistry. Cradle to Cradle Certified Product Standard. 3.0 ed. 2013.

[21] Foundation Sustained Responsibility. De MVO Prestatieladder - Eisen MVO Managementsysteem 2013:1–36.

[22] Geng Y, Fu J, Sarkis J, Xue B. Towards a national circular economy indicator system in China: an evaluation and critical analysis. J Clean Prod 2012;23:216–24. doi:10.1016/j.jclepro.2011.07.005.

[23] Damen MA. A Resources Passport for a Circular Economy. Utrecht University, 2012.

[24] Schoolderman H, van den Dungen P, van den Beukel J-W, van Raak R, Loorback D, van Eijk F, et al. Ondernemen in de circulaire economie. Amsterdam: One Planet Architexture institute, MVO Nederland; 2014.

[25] Wang J-J, Jing Y-Y, Zhang C-F, Zhao J-H. Review on multi-criteria decision analysis aid in sustainable energy decision-making. Renew Sustain Energy Rev 2009;13:2263–78. doi:10.1016/j.rser.2009.06.021.

[26] Zavadskas EK, Turskis Z. Multiple criteria decision making (MCDM) methods in economics: an overview. Technol Econ Dev Econ 2011;17:397–427. doi:10.3846/20294913.2011.593291.

[27] Zopounidis C, Pardalos PM. Handbook of Multicriteria Analysis. Springer Berlin Heidelberg; 2010. doi:10.1007/978-3-540-92828-7.